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ON TIMBER.

By A. AIKIN, Sec., F.L.S. F.G.S., &c.

Read 8th February, 1831.

My object on the present occasion is not so much to treat of the physiology and functions of the wood in living trees, as of its mechanical properties and uses in the arts. But as many curious particulars respecting timber cannot be understood without knowing something of the structure and formation of wood, I shall begin by explaining shortly as much of these as is necessary to the main purpose of this evening's Illustration.

Timber, in its most extensive signification, might, perhaps, be made to comprehend all those vegetables, the woody fibre of which is sufficiently strong to be applied to purposes of construction, resistance, and support; and, therefore, would include not only the wood of those trees that are natives of the temperate regions of the earth, but the stalks of some of the gigantic herbaceous plants of warm climates; the nettles (*Urticæ*), for example; some of the large grasses, as the bamboo, and a species of reed (*Arundo donax*), the entire class of palms, the arborescent ferns, and that other tribe of tropical plants, the canes, nearly allied to the palms. It is not my intention, however, at present, to treat of any of these, as I intend to confine myself to those substances which, in common speech and in commercial dealings, go by the name of timber.

By far the greater number of shrubs and trees belong to that division of perennial-stemmed plants called by botanists *exogenous,* that is, which increase by the yearly addition of new matter between the outer layer of wood and the inner layer of bark. A transverse section, therefore, of the trunk of such a tree presents, in general, concentric rings, more or less circular, equal in number to the years of the tree's growth. On examining one of these rings with the naked eye or with a low magnifier, it will be found to be composed of an inner ring of vertical pores or tubes, bounded or hooped in by an outer ring of more compact texture. The proportion of these parts varies greatly in different kinds of wood; and I think we generally find, that where the compact part is the narrowest it is the most solid, and is abruptly separated from the porous or spongy part, as is remarkably the case in larch wood and in others of the fir tribe. But, on the contrary, where the compact part is broader than the porous part, the line of demarcation is not so distinct, and the compact part is crossed by rows of pores: this is very observable in the oak and in other hard woods.

On examining these concentric rings more closely, we shall find a number of slender compact lines, radiating from the central ring, and, in many species of wood at least, holding their way, apparently without interruption, from the inner to the outer ring of the whole series. These lines, in their course from the centre to the circumference, become more distant from each other as they cross each successive annual ring; and when they have diverged to a certain distance, a secondary line makes its appearance between them, originating, apparently, from the spongy part of one of the annual rings, and, like the primary ones, holding its course unbroken to the outer-most ring. The plates of which these lines are sections vary much in depth in different woods: in the oak often amounting to several inches; in the maple, sycamore, &c. rarely exceeding a quarter of an inch. In some kinds of wood these radiating lines are very fine and numerous, scarcely to be distinguished by the naked eye, as in beech; in other kinds they are very visible, and are nearly equidistant from each other, as in maple; or are at very irregular distances, as in oak. Frequently they are of a different colour from the rest of the wood, as in birch, alder and maple.

From the appearances in the transverse section which I have just described, it is evident that the trunk of a tree consists of a number of cylinders, or rather cones, one within the other, divided by a multitude of thin compact vertical plates, of various depths, running from the axis of the trunk to its circumference. These plates are commonly known by the name of silver grain, from their great brilliancy; and, when cut obliquely, they conduce to those variations and undulations of light so much esteemed in ornamental cabinet ware. You must bear in mind, however, that, although I have spoken of compact and porous parts, even the most compact, when viewed by high magnifiers, seem to be made up of distinct bags or cells; so that the really solid matter, even in the most dense woods, is comparatively small.

The bark, like the wood, consists of annual concentric layers, the new layer of bark being formed on the surface of the new wood. As many layers of bark, therefore, are produced as of wood, and, as the new yearly deposit of wood and bark is formed between the wood and bark of the preceding year, the old bark is continually pushed more and more outwards: but, during this process, the wood of the trunk is continually enlarging in circumference; the outer layers, therefore, of bark become incapable of containing it, and crack and fall off. In most trees, many layers of the dead outer bark remain on at the same time and detach themselves insensibly by small pieces, which occasions the rough, rugged furrows in the older trunks of the oak, the elm and the ash. In other trees, as each external layer of bark dies, it falls off, either in large flakes, as in the plane; or in coarse fibres, as in the vine; or is insensibly cast off in small scales, as in the beech and hornbeam.

During winter, the vital powers of the tree are nearly inactive; but early in spring the roots take up from the ground a large quantity of fluid, that is, of water holding a small proportion of salts and other substances in solution. The water, when taken up, comes in contact with vegetable matter deposited during the former year in the roots and in every part of the living wood of the tree, but chiefly in the sap wood, and, dissolving it, is converted into sap. I am not acquainted with any experiments for the purpose of ascertaining the nature of the substance which, when dissolved in water, forms sap; but as we know that sap is capable of the vinous fermentation and, when boiled down, yields sugar, it is reasonable to conclude, that the substance in question is either sugar or a vegetable principle capable, when acted on by water in the living plant, of yielding sugar. This latter is the more probable supposition, both because wood is not sweet to the taste, and because there is the strong analogy in its favour of the conversion of starch into sugar during the germination of seeds, a process apparently very similar to the unfolding of buds. The sap rises to the furthest branches and sprays by means with which we are not well acquainted, and thus conveys a due supply of nutriment to every bud in the tree. In the mean time, a separation takes place of the outer layer of wood from the inner layer of bark, and the space between them is occupied by a viscid half-gelatinous fluid. The buds, as soon as they begin to unfold, shoot down one fibre or root each, which, creeping down among the viscid fluid just mentioned, at length reach the extreme roots of the tree, and thus, by their close lateral adhesion to each other, inclose the last year's wood with a layer which itself becomes the compact part of the new wood.

Since, therefore, each annual deposit of wood consists for the most part of the fibrous roots of the buds, it might be expected that all those circumstances which influence the number of the buds, their due and healthy unfolding, and the size and vigour of their descending fibres, will also affect the thickness and compactness of the corresponding layer of wood. There is every reason to believe that this is the case to a certain degree; and it may be worth while to pursue the inquiry with some minuteness, as several matters of interesting speculation and practice are connected with it. If we look at a transverse section of any tree, we shall find a notable difference in thickness between many of the annual layers. Of English trees, none presents so great a difference in this respect as the oak; and, agreeably to this, the fact must be familiar to every one, that none of our trees is so liable to have its young foliage injured or destroyed by cockchafers and other insects, and by dry blighting winds.

If, of two concentric rings, the difference in breadth, whatever may be its amount, be the same, or nearly so, in every part of the ring, the cause of such difference is one which has affected the whole tree; such are favourable or unfavourable seasons with respect to warmth or moisture, insects, blights and spring frosts. Probably, also, if a maiden tree (one which has not been lopped) grows in a coppice composed of trees equal to itself in height, the year before and the five or six years after felling such coppice, would be indicated, respectively, by a narrow ring, and then by a series of others gradually increasing in breadth; as, in the former case, the tree would have been in the least degree, and, in the succeeding years, in the greatest degree, exposed to the action of free air and light. A severe pruning of a timber tree has also the effect of very notably diminishing the thickness of the annual layers subsequently deposited, till the number of buds which existed previously to the pruning has been restored.*

But in many trees a great difference is observable in the same ring in opposite parts of it; and where this affects all, or nearly all, the rings, it shews that some partial cause has been operating during a series of years. Some of the woods collected by Dr. Wallich in the mountains of Nipal, and presented by him to the Society, afford very extraordinary examples of this variation; and, in a less degree, it is by no means an uncommon occurrence. The cause of it is generally considered to be the position of the tree with regard to the sun, that side on which the rings are broadest facing the south. I do not know how far the fact has been ascertained in any particular case; but, if this were the sole, or even the chief, cause of the appearance, it ought to affect every tree that grows, either singly, or in an avenue or hedge-row extending east and west. The subject has been discussed by M. Duhamel, in his great work on timber,* and he states, as the result of actual experiment, that in those trees which grow surrounded by others in a wood or forest, each concentric ring is equal, or nearly so, in every part of it; but that the trees on the margin of a wood have the broad part of every ring facing outwards; for, says he, the branches on the side towards the country are longer, and better furnished with foliage, than those which project towards the wood, because the roots which feed them have a longer and interrupted range. In a rocky country, there may be many situations in which the roots of a tree shall starve on one side and luxuriate on the other; and when such accidentally concur with a north and south aspect, such exaggerated specimens as those just now alluded to may be the result.

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* Transactions of Society of Arts, vol. xlviii. p. 214.

Another variety in the concentric rings deserves notice, namely, that they are sometimes elliptical, being considerably broader in two opposite points than they are in the points at right angles to these. A closely planted line of trees would exhibit this appearance in the wood of each of them, except the first and last in the row; for the roots and boughs would be cramped in two opposite directions, and at full liberty in the contrary ones; the wind, likewise, would affect them chiefly at right angles to the direction of the row; and, when trees are prevented from swaying except in one line, the principal deposit of wood will be in that line, as Mr. Knight has proved by experiment.

In very young trees, there is no perceptible difference in the several layers of which they are composed; the whole is sap-wood, on which account, indeed, they are technically called saplings. But, after ten or a dozen annual layers have been deposited, the two or three interior ones will begin to be distinguished from the others by a deeper colour, a greater specific gravity, a superior hardness, strength and durability: they have passed into the state of timber, and the chief vital operations going on in them seem to be the permanent deposit in their cells of colouring matter, resin, and other secretions. Still, however, some of the solid ingredients of sap are stored up in them, during the autumn, for the consumption of the spring and summer; for young oak felled in December and January, and weighed immediately without drying, is of greater specific gravity than when felled at any other time; while that felled in June and July has the least specific gravity.

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* Sur l'Exploitation des Bois.

The number of layers of sap-wood in a tree continues always the same, or nearly so; and if we estimate these, on an average, at seven or eight, it follows that the timber, or heart, is continually increasing with each successive annual layer, the density and hardness of the timber, in any part, usually corresponding, in a great degree, with its nearness to the centre, or axis of the tree. At length, however, the central layer acquires the utmost degree of density and hardness of which it is capable, and afterwards other layers in succession. Now, it is manifest that, if this state were permanent, the increase of a tree would be absolutely indefinite. But every thing that lives is destined to death; and trees, although their life, in many cases, is protracted through centuries, at length die of old age. It appears probable, when the central layer has acquired its greatest density, by the deposition of resin, colouring matter, &c., that the ascent of sap in it is greatly impeded, and at length ceases. The layer next the central one soon passes into the same state, and many others in succession. The lateral branches, in proportion to their nearness to the central one, attain the same height as this, and afterwards stop. When, therefore, a tree becomes round-headed or flat-topped, its season of growth has passed, and it is in a state of maturity. Of all our common deciduous trees the lime and the horse-chestnut shew this change the most remarkably, the outline of the foliage of both of them when young being conical, and when old nearly globular (I am speaking, of course, only of such trees as stand by themselves, and in situations where their natural form is not interfered with, either by art or by natural causes). Of evergreen trees, the common fir, as being within every one's notice, may be cited, the form of which when young is an acute cone, and when old is nearly flat-topped. How long a tree continues in a state of maturity I do not know, there being no recorded experiments on the subject. It is probable, however, that each species of tree has what may be called its natural term of growth and maturity, and that in this respect there is a great difference between different species; the beech and sycamore, for example, passing through these two states in a much shorter time than the oak or the wild pear, and this independently of the adventitious circumstances of soil, climate, and exposure, by which their natural period may be hastened or retarded.

If a tree be felled that has been for some years at its full growth, the central layers of timber, instead of being of greater specific gravity and hardness than the others, will, on the contrary, be found to be lighter, softer, and in a remarkable degree weaker. In these layers, therefore, life has probably ceased, and decay has begun: the moisture by which all parts of a standing tree are penetrated, and which maintains the life of all the living layers, has a directly contrary effect on the dead ones, facilitating their decay and decomposition. Rottenness of the dead layers ensues, the axis of the tree becomes an open pipe, through which the rain-water soaks and the air enters; decay of each layer in succession from the centre follows more quickly than the application of new layers on the outside, the roots partake in the destruction of the layers which they supplied, and, finally, the trunk, having become a mere shell, is overthrown by some violent storm of wind.

From what has been said, it is evident that in all healthy trees there is a period of maturity, in which a great many layers have passed to the state of timber, while the central one still retains as great a degree of strength and density as it ever possessed. This, therefore, is the precise time to fell the tree, if our wish is to have timber of as large scantling as possible, and at the same time perfectly sound. How long this time continues, is not known, and on the whole it is better to anticipate it by a few years than to incur the hazard of its passing over. A tree has certainly passed its prime if the leaves change colour in autumn earlier than those of other trees of the same kind, and especially if the leaves on the upper branches are coloured, while those on the lower ones are still green. Also, if the upper branches die, in which case the tree becomes stag-headed; if the bark cracks and peels off in unusually large pieces; if it is overloaded with lichens or moss; or, finally, if the sap becomes extravasated and runs out through rifts in the bark.

Two circumstances remain to be mentioned, which, perhaps, more than any others, affect the quality of growing timber: these are, exposure and soil.

A tree surrounded by others must grow as fast as its neighbours, or not at all. Every one knows, even from experience of the plants in his windows, how eagerly all vegetables turn the upper surface of their leaves to the light, how they shoot solely in that direction, and much more rapidly than usual, though with diminished vigour, in order to reach the light if it enters a little above them. In a dense wood the trees of most robust constitution and quickest growth take the lead, and, by intercepting the light from the weaker or more slow-growing, occasion a somewhat sickly and unnatural rate of growth in these latter, to secure their share of light. All the energies of the tree are directed to its longitudinal increase; the side-branches are rare and slender, and soon decay, the stem spindles up, in diameter a mere stick, even when many feet high, in consequence partly of the unnatural rate of its elongation, and partly of the absence of leaf-buds, except at the top of the tree, which occasions the annual deposits of woody layer to be extremely thin. The final result of these circumstances is, that the weak perish and the strong and vigorous alone remain, with clean drawn up trunks, that in time acquire their proper thickness, but free from lateral branches. The timber of such trees consists of straight fibres; it is rather soft, splits readily, and when cut into beams or planks possesses great strength and elasticity, because each fibre bears an equal share of the load laid upon it.

On the contrary, when a tree grows in an open space it rises less rapidly, and rarely attains so great a height as it does in the former situation; it throws out large lateral arms on all sides, the fibres of which, as they join those of the trunk, interfere with them, and thus mutually compel each other to take a curvilinear direction. The timber of such a tree will be coarse, knotty, contorted, unfit to cut into beams or planks to sustain pressure, but hard, tough, and well qualified to resist blows, and the wear and tear of friction. For the same reason the butt of all trees, that is, the part immediately above the roots, is tougher and harder than the stem.

If exposure thus modifies the quality of timber, soil will be found likewise to produce no unimportant effect. To every tree there is a soil which suits it best; for although many will grow in very different soils, the timber which is the product of them differs accordingly in magnitude, hardness, strength, and durability. In a country fully peopled like England, the best soils are appropriated to agriculture; and our modern plantations are chiefly confined to exposed hilly tracts, or to land more sheltered, but too barren for arable crops or pasturage. Hence it is that in England the giants of the forest have for the most part passed away, and our posterity will know them only by history or vague tradition.

The time of year in which trees ought to be felled has been a subject of much controversy; that is, whether it should be done in winter, before the rise of the sap, or in spring, when the sap is most abundant. On this question, as on most others respecting timber, there has been a great deal of vague talk, because it is much easier to make a theory or an assertion than an experiment. We find, however, in the large and elaborate work of M. Duhamel, *sur l'Exploitation des Bois*, an extremely valuable series of experiments relating to this inquiry, the results of which I shall now state. The experiments, indeed, were made only on oaks, but are probably applicable to all other deciduous forest-trees. Oak felled in December and January, and weighed without drying, is of greater specific gravity than that felled in March and April. Winter-felled oak, by drying under a shed for three years, lost somewhat less weight than oak of similar quality spring-felled. In another set of experiments, winter-felled oak, after being dried under a shed for four years, and then in a stove, lost more than one-fifth less than spring-felled oak by similar treatment. Now, it is a general rule, that of two samples of oak, equally dry, that is the strongest which has the greatest density; but M. Duhamel found this to hold good with respect to different oaks only if felled at the same time of the year. He concludes, therefore, that, as far as the strength of timber is concerned, this quality is little, if at all, affected by its being felled in winter or in spring.

It is likewise asserted, that spring-felled timber is much more liable to decay than that which is winter-felled; and the determination of this point was the object of another series of experiments, in which M. Duhamel found that there is really a difference in this respect in favour of winter-felled wood, but by no means to the extent that is generally supposed. Against this is to be set the much greater facility of stripping the bark in spring, when the adhesion of it to the wood is nearly destroyed, as I have stated in a former part of this paper, a circumstance that deserves consideration when, as in oak, the bark is often one-fourth of the value of the timber.

Another mode of taking down timber, which appears to have prevailed formerly in Northumberland and Durham, was to strip the bark from the trunk while the tree was standing, and not to take it down till a year or, perhaps, two years after. The Royal William, and two or three other ships in the Navy, remarkable for having lasted seventy years or more, were built of north-country timber, in all probability prepared in the way just mentioned. The effects of this treatment were investigated by Duhamel, and the following are the results obtained. Four oaks 2½ feet in girth, one 3 feet, and two 6 feet in girth, were stripped of their bark in the month of May, from the root to the division of the trunk into branches. The trees, with the exception of one of the small ones, which died early in the autumn, carried their leaves the usual time, and produced another crop in the second spring. They all died in the course of that year, and were cut down in the third spring, having stood two years unbarked. After drying for a year, they were cut up, and compared with others of equal size, spring-felled as usual, stripped, and dried for three years. The former, though apparently in the same state of dryness as the latter, were far more difficult to saw, their specific gravity was greater in the proportion of 6 per cent, and their resistance, when loaded to breaking, was on an average full 14 per cent greater. For naval timber, therefore, this practice seems likely to be attended with very beneficial results, notwithstanding the increased expense of taking off the bark of the trunk while standing, of sacrificing much of the bark left on the branches, and of subsequently converting the timber on account of its much greater hardness.

What degree of seasoning is required to enable timber to resist for the longest period the progress of natural decay, that is, decay from spontaneous decomposition, as distinguished from that which is effected by insects, either in their larva or in their perfect state?

This is a question easier asked than answered, both on account of its extent and complication, and because we are still in want of accurate experiments on some of the leading points of inquiry.

I believe the only kind of seasoning that has ever been in use, at least in general use, is slow drying, with as free an exposure to air as circumstances will allow: the greater the surface of the wood in proportion to its bulk, the more quickly is it seasoned. On this account it is that the timber employed in common carpentry and in cabinet-making is sawn into planks, and that used in ship-building is rough-hewn nearly to the shape required before the seasoning commences. There is likewise another reason for so doing, namely, that wood is much easier worked wet than dry, and a considerable saving of labour, and therefore of expense, is made by converting timber when in this state. The larger the piece of timber, and the closer its grain, the longer is the time required to season it, that is, to evaporate all the moisture which it will give out in ordinary states of the atmosphere. In experiments on this subject, the wood is weighed from time to time, and the seasoning is not considered as complete so long as the specimen continues to lose weight. A piece of oak large enough for ship-timber, judging by this test, will not be thoroughly dried in less than eight or ten years, and other woods in proportion. The sap-wood usually decays in the very act of seasoning, and therefore is rejected.

On account of the length of time required for complete seasoning, it may be assumed that almost all timber of any size, such as is required for buildings, both naval and domestic, is insufficiently seasoned; but if, when placed in a house or ship, it is exposed to a tolerably free circulation of air, evaporation will still go on, and the wood may at length be seasoned, without having incurred any injury. If, on the contrary, evaporation is prevented by a covering of paint, or the surface, unpainted, is exposed to a close damp air, decomposition will speedily ensue; the timber acquires the smell of mushrooms, and white filaments will be seen penetrating into those parts of the wood the cohesion of which has been weakened by the commencement of decomposition. These fibres are the living roots of a species of fungus, which, in circumstances favourable to its growth, will, in an incredibly short time, penetrate through the whole substance of a piece of timber, and totally destroy its cohesion. This species of decay is called dry rot, and is characterised by the rifts and ruptures which it occasions directly across the fibres of the wood. It not only destroys the piece in which it originates, but passes to those pieces that happen to be in contact with the first, even though these latter may have been sufficiently seasoned to have shewn no previous signs of decay. It is this formidable infection which of late years has made such ravages in the navy, and in buildings of all kinds where circumstances occur favourable to its developement.

Far different from this is the common rot or decay which seasoned timber undergoes while freely exposed to the atmosphere, by the concurrent action of moisture and air: the whole cellular texture is first weakened, and then, first the soft parts and afterwards the harder ones break down, and are reduced to a brown powder. It does not, however, appear that there is any thing infectious in this decay, except so far as that insects, which are attracted by the decaying wood, on which they feed and in which they bore their hiding-places, may also extend their operations to sound timber in the neighbourhood, and thus hasten its destruction.